A model study of controlling factors for ultrafine particle concentrations in the Antarctic coastal region in summer

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There are few effects of anthropogenic air pollution on the secondary particle constituents in the Antarctic atmosphere. It is a suitable place to study the nucleation and growth processes of secondary particles of natural origin. Ground based observations suggested that nucleation of natural secondary particle will occur upper atmosphere around Syowa Station (69.00° S, 39.58° E, 29.18 m a.s.l.) (Osada et al., 2010), and that nucleation occurs in the lower free troposphere (Hara et al., 2011).

Nucleation and growth rates are connected with gaseous sulfuric acid, and organic vapor. Oceanic dimethylsulfide is a major source of sulfuric acid in Antarctica, and the ocean also provide both primary and secondary organics and water vapor. There are possibilities that nucleation will occur also in the marine or coastal boundary layer near Syowa Station.

A 0D-BOX model with the MADMS (Modal Aerosol Dynamics model for multiple Modes and fractal Shapes; Kajino, 2011) was developed to evaluate the possibility of new particle formation and growth to diameter of 10 nm in the boundary layer, to explain relations between water mixing ratio and particle concentrations of $D_P > 10$nm observed by JARE58 and JARE60 around S17 (69.02° S, 40.09° E, 600 m a.s.l.) using UAV (black solid circles in Fig. 2). The model includes the processes of sulfuric acid-water nucleation, condensation growth by sulfuric acid, condensation sink of sulfuric acid and coagulation sink of ultrafine particles onto accumulation mode particles, with size distributions observed at the ground of S17.

The most efficient formations of $D_P > 10$ nm particles occur around relative humidity of 80% (Fig. 1), because of high nucleation rate and low relative humidity dependence of coagulation loss. $D_P > 10$ nm particle concentrations after fixing time from nucleation start calculated at a relative humidity of 80% show anti-correlations with water mixing ratio, which is corresponding to dew point (Fig. 2), similar to the relation of upper boundary of observed by UAV. They suggest the condition of low temperature and high relative humidity, which is common around the upper boundary layer, are suitable to new particle formation in the coastal Antarctica.

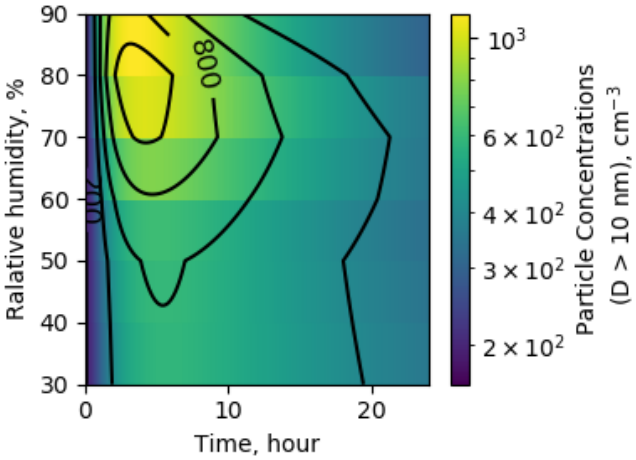

Figure 1. Temporal variation of particle concentrations at various relative humidity conditions.
Temperature: 260 K, SO_2 concentration: 500 pptv.

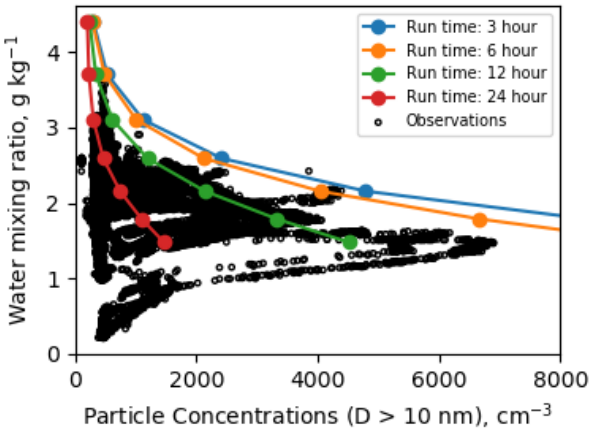

Figure 1. Correlations of water vapor mixing ratio v.s. particle concentration by UAV observations (Black circle, Haraguchi et al., SPS poster, 2019) and those at a fixed period after the nucleation start at a relative humidity of 80% and SO_2 of 500 pptv by model calculations. (Blue, orange, green, and red show 3, 6, 12, 24 hours after nucleation start, respectively).

References

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